Sound System

Design, Sources, Scene

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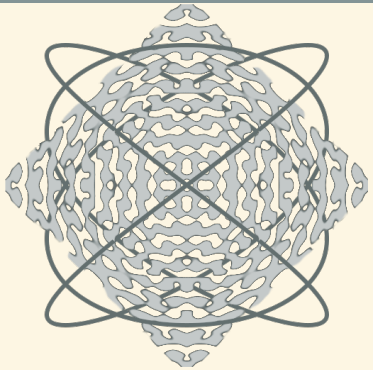
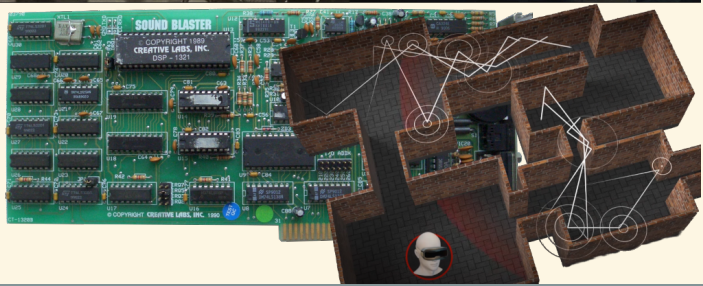


Introduction

Sound in Games

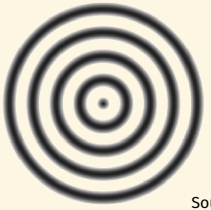
- User Communication [2]
- Theme, Mood, Emotion [6]
- Movie × Game: Interaction
- Essential Part of Games [3]
  - User Interface
  - Interactive Sounds
  - Communication
  - World Immersion
- Long History
- → Audio System

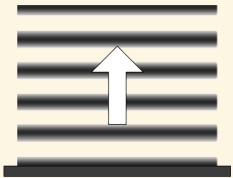


Sound Theory

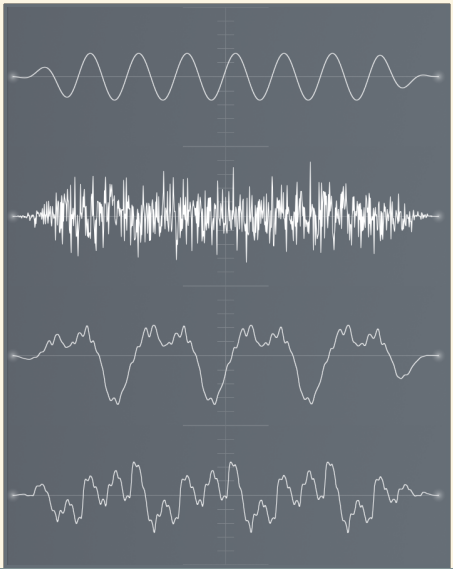
Physics of Sound

- Compression Wave
  $p(t) = p_a(t) + p_s(t)\ [Pa]$
- Change in Time $\rightarrow$ Signal
- Sound Sources
- Propagation in Medium
  - Wave Properties: Reflect, Refract, Diffract
  - Absorption & Falloff: $p \propto \frac{1}{r}$ $I \propto \frac{1}{r^2}$





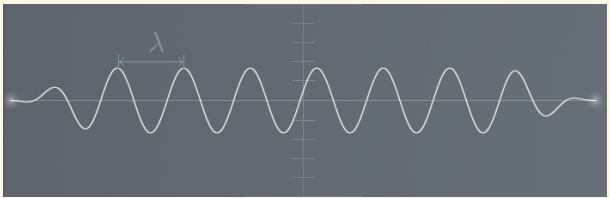
Source: Game Engine Architecture [4]

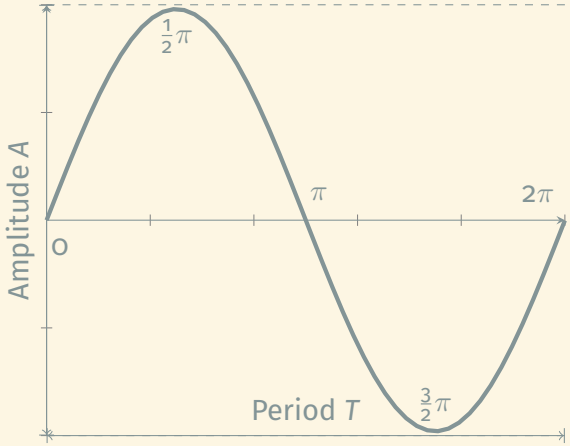


Sound Wave Attributes

- Periodic Nature

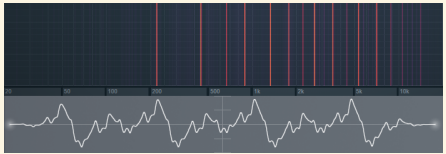
- Period T $[s]$
- Frequency f $[Hz]$
- Phase ϕ $[rad]$
- Speed v $[ms^{-1}]$
- Wavelength λ $[m]$

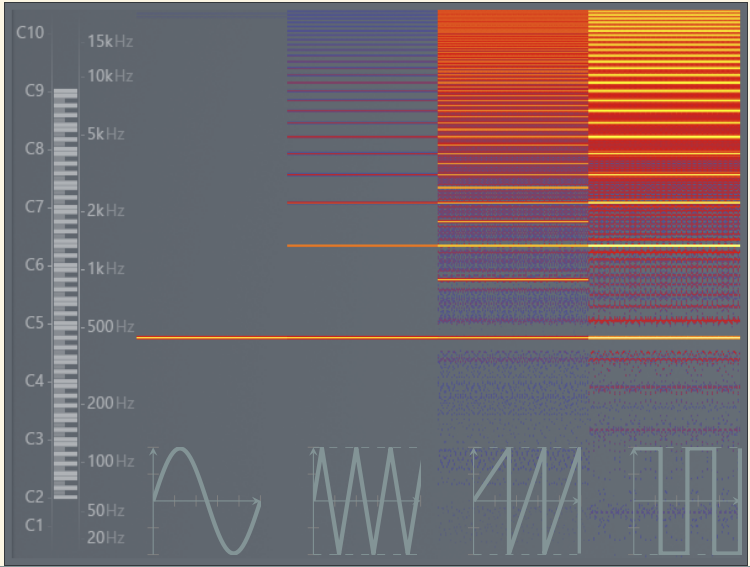




Sound Spectrum

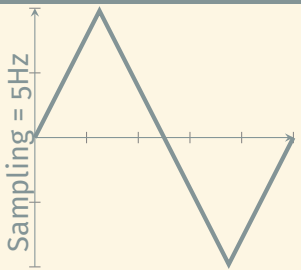
- Signal = Sinusoid Sum
- The Spectrum
- Fourier Transform
  time ⇄ *frequency*
- Wave Shapes
  - Sine
  - Triangle
  - Sawtooth
  - Square

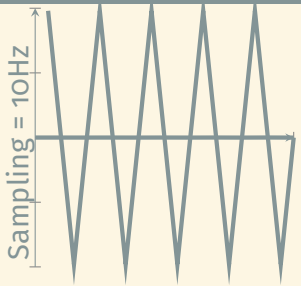


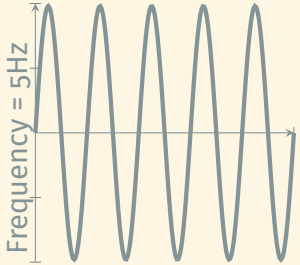


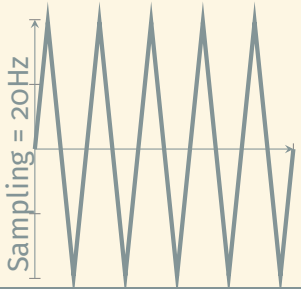
Sampling

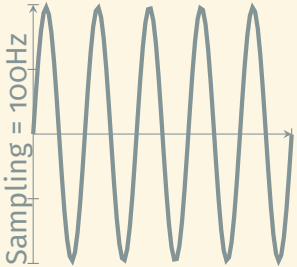
- Analog → Digital
- AD & DA Converters
- Sampling Frequency
  Nyquist–Shannon Theorem
- Quantization











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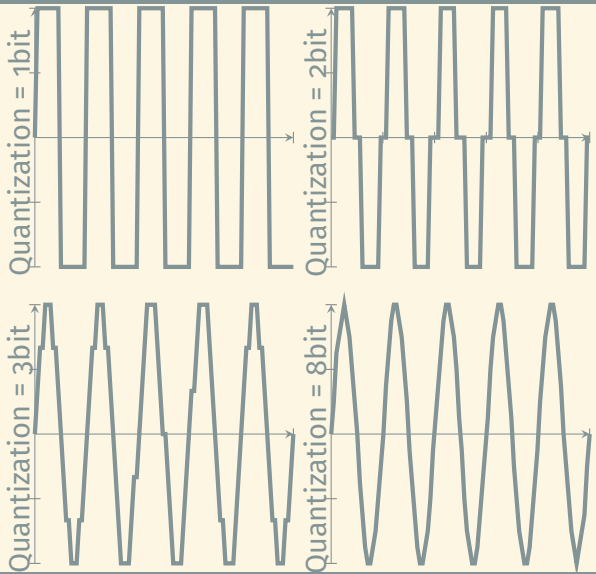
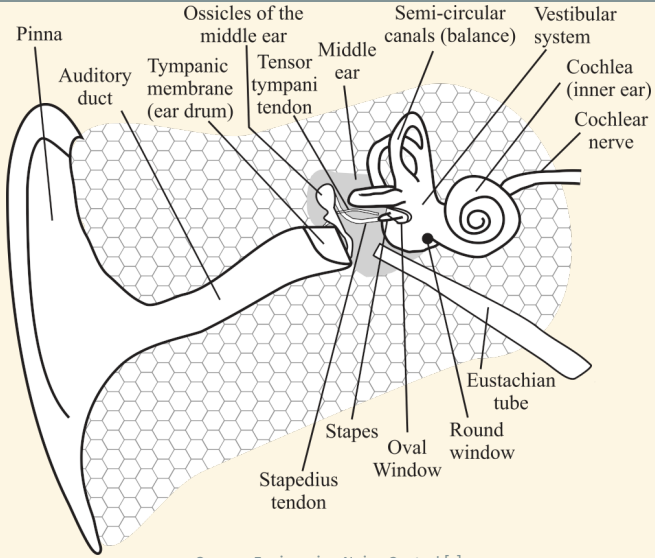


Perception of Sound

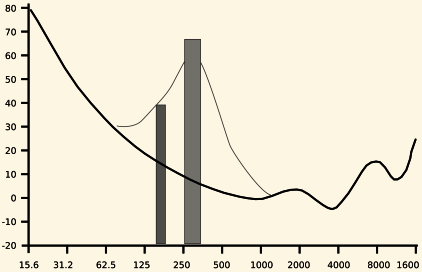
- Ear Construction [1]
  - External Ear
  - Middle Ear
  - Internal Ear
  - Neural Encoding
- Sound Loudness [4]
  - Sound Pressure
    $I \propto p_{rms}^2 = \sqrt{\frac{1}{t}\int p(t)^2 dt}$
  - Wide Dynamic Range
  - Logarithmic → decibels $[dB]$
  - Sound Pressure Level (SPL)
    $L_p = 10\, log_{10}\left(\frac{p_{rms}^2}{p_{ref}^2}\right)$



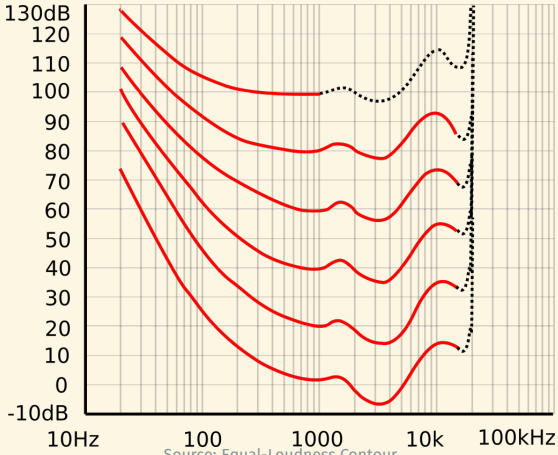
Source: Engineering Noise Control [1]

Psychology and Acoustics

- Signal Processing → Perception
- Limits of Hearing : 20 *Hz*–20 *kHz*
- Psychoacoustics
  - Fletcher-Munson Curve [5]
  - Auditory Masking ⇄ [1]
- Gestalt Psychology



Source: Psychoacoustics



Source: Equal-Loudness Contour

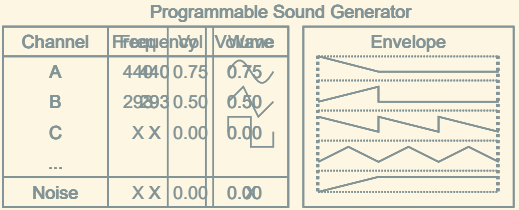
Sound Design

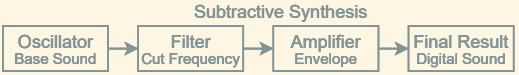
Historical Development: 8-bit

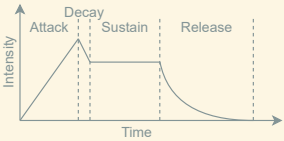
- Arcade Machines [2]
  - Specialized Hardware
  - Digital Recording ⇝ DAC
  - Sound Synthesis ⇝ PSG
- Home Consoles [2]
  - Shared I/O Chip
  - Programmable Sound
  - Looping Tracks
- Personal Computers [2]
  - The Beeper
  - Programming & Memory

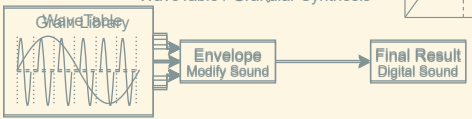
Historical Development: 16-bit

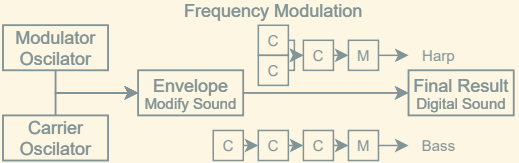
- Programmable Sound Generator
  - Voice Channels
  - Envelope & ADSR
- Subtractive Synthesis 1
- Frequency Modulation Synthesis [2]
  - Frequency Modulation (I) (II)
  - Synthesizer (I) (II)
- Table-Based Synthesis
  - WaveTable
  - Granular





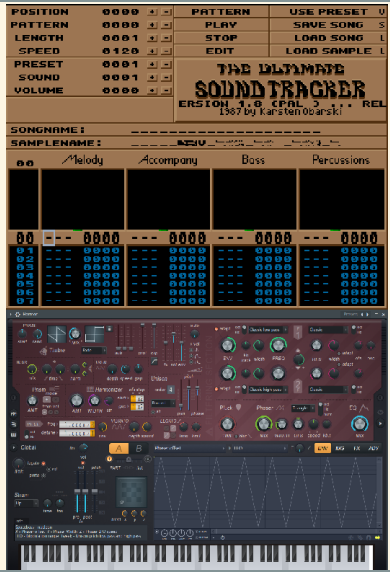






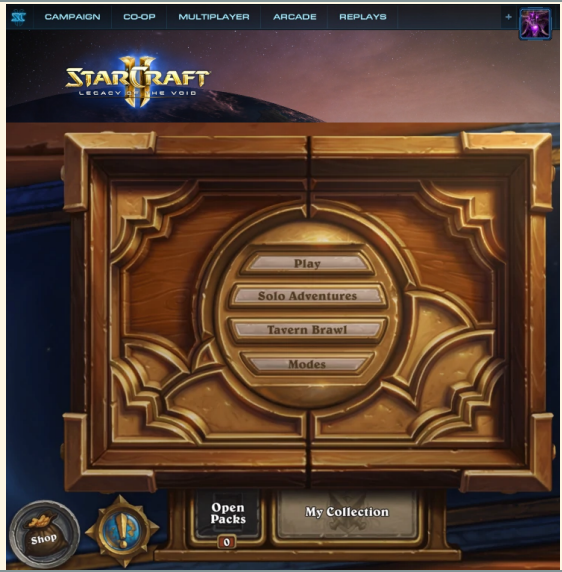
Historical Development: Sequencing

- “Programmer-Composer”
- Sequencer → Synthesizer
- MIDI
  - Standard Format
  - Command Interface
  - Hardware Dependant Sound
- iMUSE [2] (I)
- Music Tracker (I)
- Digital Audio Workstation



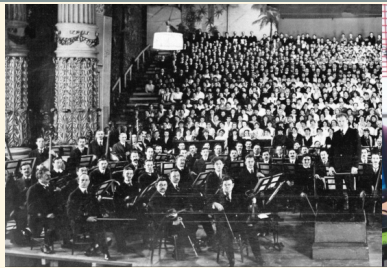
Digital Sound Design

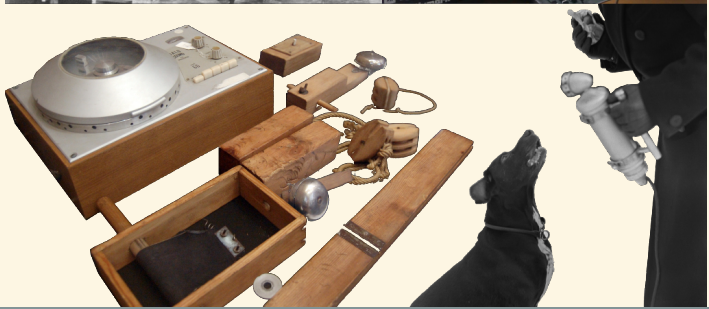
- DAW → Samples & Synthesis
- Magic of Sound Design (I)
- Diegetic vs Nondiegetic [2]
- Music Track
- Sound Effects Library
- User Interface (I)
  - Digital
  - Mechanical



Physical Sound Design

- Physical × Synthesis
- Recording + Touch Up
- Sound Effects
- Music & Voice
- Foley (I) (II)

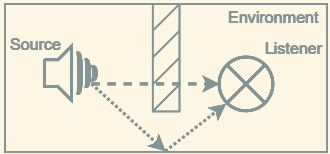


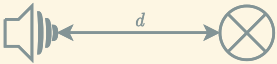


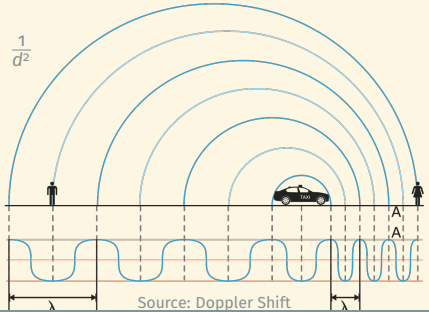
Implementation

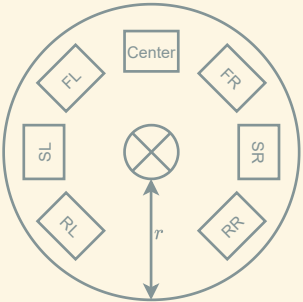
Rendering the Audio

- Direct PlayBack?
- Modeling the World [4]
  - Environment
  - Sound Sources
  - Listeners
- Sound Synthesis & Triggers
- Occlusion → Indirect
- Spatialization
  - Distance Attenuation $\frac{1}{d^2}$
  - Volume Panning
- Acoustic Modeling
- Doppler Shift
- Real-Time Tricks



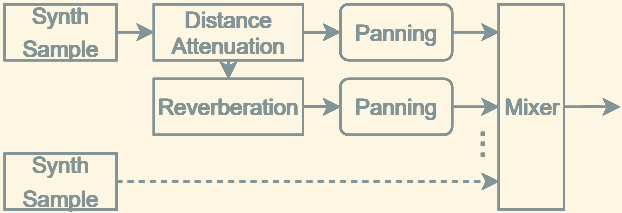


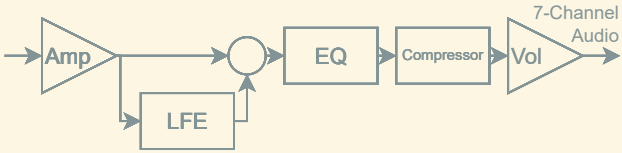


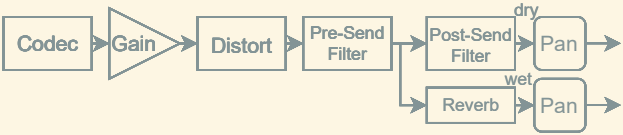


Audio Engine Architecture

- Audio Processing Pipeline
- Sound Voices
  - Degree of Polyphony
  - 2D × 3D
- Voice Pipeline
- The Master Mixer
  - Mixing Voices
  - Depth & Rate Conversion
- Output Bus
- Audio Engines:
  - System Audio
  - FMOD
  - Wwise



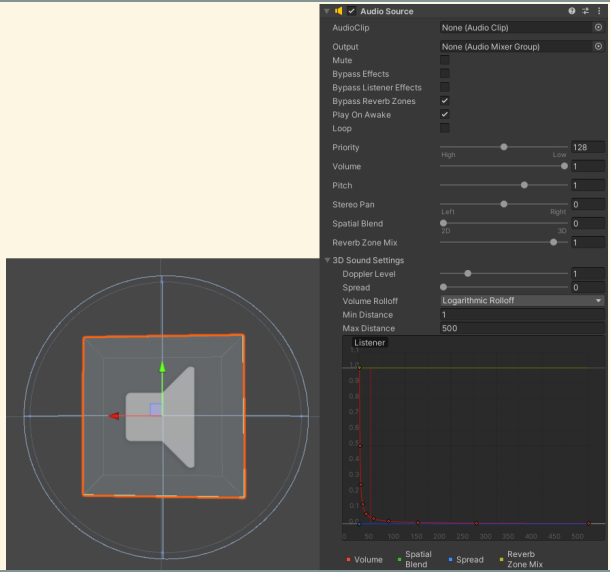




Audio in Unity

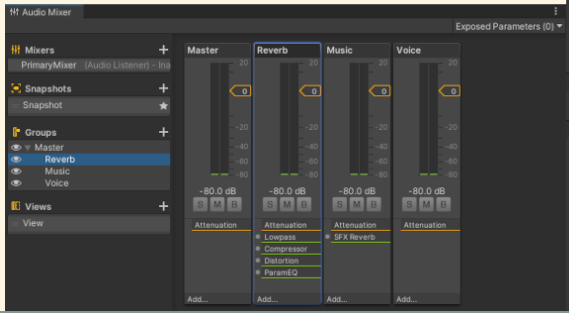
Audio Overview

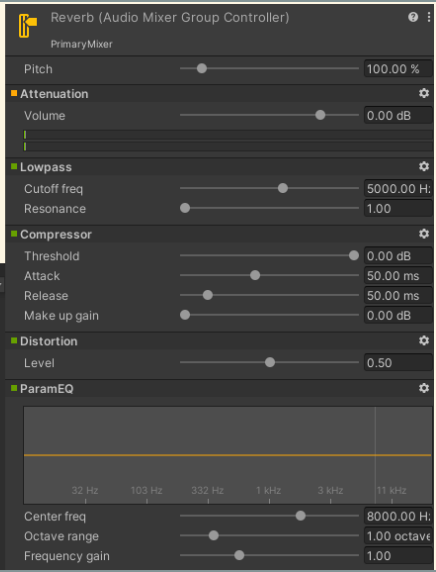
- Hierarchy Integration
- Audio Source & Listener
- 2D and Full 3D
- Audio Asset Support
- Profiler Section
- Tracker Modules



Audio Mixing

- Spatial Blending & Distance
- Equalizer → Groups
- Filters, Parametric Equalizer
- Effects: Reverb, Echo, ...

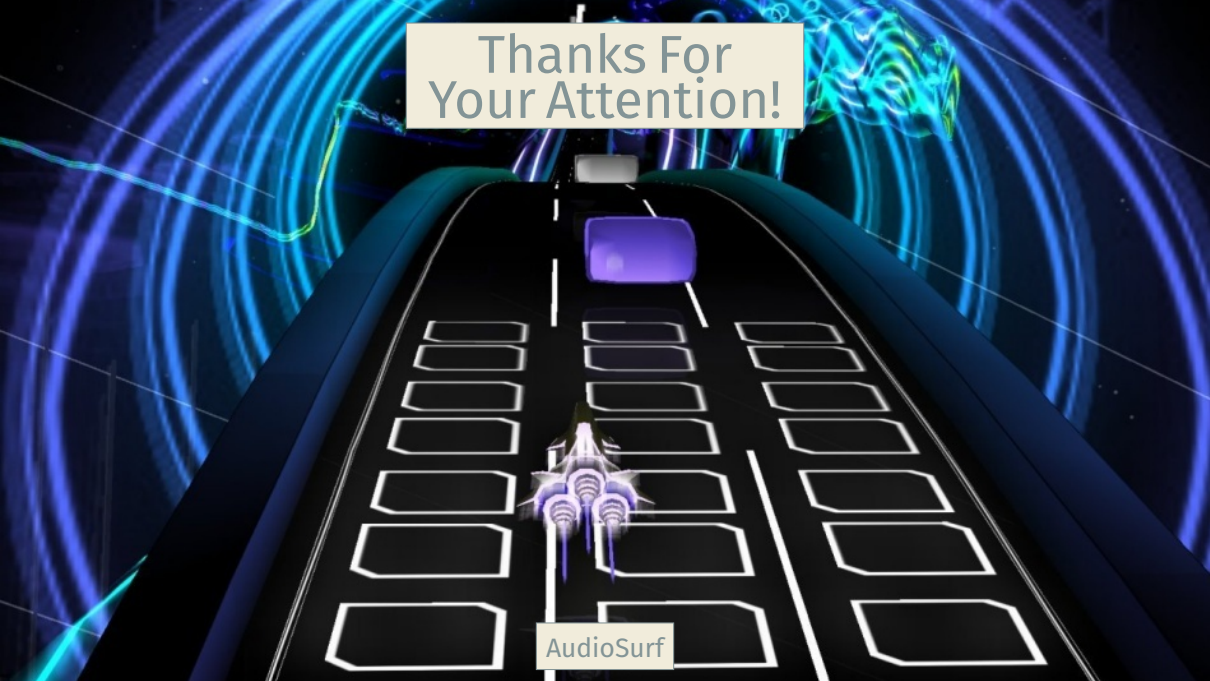




Additional Resources

- [YouTube] Trackers: the sound of 16-bit
- [YouTube] Augmented Second - An Analysis of the Arabic Interval
- [YouTube] Signal Processing for Sound Design
- [YouTube] Magic of Making Sounds
- [Software] Sonic Pi

Source: Toxic Biohazard Synthesizer


Thanks For
Your Attention!
AudioSurf

References I

[1] David Bies. ***Engineering Noise Control.*** London: CRC Press, 2017. ISBN: 9781498724050.

[2] Karen Collins. ***Game sound: an introduction to the history, theory, and practice of video game music and sound design.*** Mit Press, 2008.

[3] Jaime Cross. ***Game Audio and the 50% Fallacy.*** https://speedyjx.com/2015/06/04/game-audio-and-the-50-fallacy/. 2015.

[4] Jason Gregory. ***Game Engine Architecture, Second Edition.*** 3rd. USA: A. K. Peters, Ltd., CRC Press, 2018. ISBN: 1351974288.

[5] Jared H. ***Fletcher Munson Curve: The Equal Loudness Contour of Human Hearing.*** https://ledgernote.com/columns/mixing-mastering/fletcher-munson-curve/. 2021.

[6] David Sonnenschein. ***Sound design: The expressive power of music, voice, and sound effects in cinema.*** Michael Wiese Productions Studio City, 2001.